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A Collaborative Computer for the Mars Team

- **MERBoard enables scientists and engineers to easily display, annotate, distribute, store, and retrieve data**
- **Its interactive design lets users focus on the task, not the tool**

NASA's Mars Exploration Rover (MER) mission has sent two robot rovers, Spirit and Opportunity, to search for evidence that water once existed on the Red Planet. The mission requires hundreds of scientists and engineers to collaborate at multiple levels to develop appropriate science and engineering strategies for execution by the rovers.

The role of human-centered computing
The CICT Program has played a key role in the development of technologies to support the MER operations team. One of these technologies, funded by CICT's Intelligent Systems (IS) Project, is the MERBoard. The MERBoard is a collaborative computer that assists the MER scientists and engineers at NASA's Jet Propulsion Laboratory (JPL) in performing complex operations tasks.

Michael Shafto, manager of the IS Project's Human-Centered Computing (HCC) subproject, says, "NASA missions, such as planetary exploration, often depend on human-centered systems that consist of Earth-based expert teams and remote robots, such as the Mars rovers, collaborating to maximize mission science return. Our goal is to drive development of new technologies that support this mode of operation. The MERBoard is a prime example. Jay Trimble and his team at NASA Ames Research Center observed the MER team's operations in early Earth-based field tests and built the MERBoard to overcome the constraints they saw impeding the collaborative process."

How scientists inform rover operations
"The translation of scientific goals into instructions for the rover is a complex, team effort," says Jay Trimble, principal investigator and group lead for Ubiquitous Computing and User-Centered Design at Ames' Computational Sciences Division.

"Upon receiving data from the rover, the scientists review and analyze it to identify future targets for inquiry. They work in five theme groups: atmospheric science, geology, geochemistry and mineralogy, soil/rock physical properties, and long-term strategic planning. These groups must integrate their inquiries into a strategy for prioritizing the rover's scientific observations. They then formalize this strategy for the engineers who develop the rover commands. This is a major challenge to the collaborative process."

Detecting and overcoming constraints
"The members of our HCC group are cross-disciplinary, with knowledge of computer science, anthropology, and cognitive psychology," says

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The MERBoard (left) places information and images literally at the fingertips of the Mars Exploration Rover (MER) scientists and engineers. They can quickly and easily share, view, annotate, and store data and images with the touch of a finger, using drag-and-drop functionality.

Technology Spotlight

Technology
MERBoard (Mars Exploration Rover Board)—a collaborative, interactive computing platform

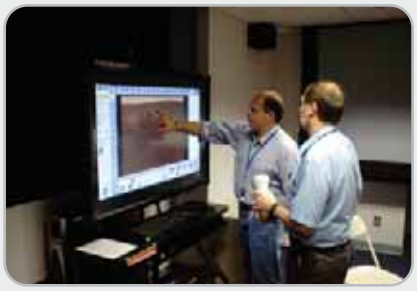
Function
Enables scientists and engineers to collaborate effectively in planning surface operations for planetary exploration rovers

Relevant Missions
- Mars Exploration Rover (MER)
- Other tele-robotic missions

Features
- 50" touchscreen plasma display with electronic whiteboard, Web browser software, and screen-capture tool
- Interactive tools
- Remote access and control
- Virtual network computer tool for linking MERBoards
- Tool for annotating images and data
- Drag-and-drop storage to accounts
- Easy screen tabs for selecting tools
- Plug-ins for customization

Benefits
- Enables scientists and engineers to display, annotate, distribute, store, and retrieve data
- Facilitates real-time collaboration
- Enables easy storage and archiving of mission data and operations
- Unifies common tasks for heterogeneous applications and plug-ins
- Supports customization for mission-specific tasks

Contacts
- Jay.P.Trimble@nasa.gov
- Michael.G.Shafto@nasa.gov



MER scientists use MERBoard to observe targets of geological interest on the wall of the crater in which the Mars rover, Opportunity, landed.

Trimble. "By observing the MER teams in early field tests, we saw how their existing work tools and practice could be augmented to increase collaboration and productivity.

"For example, to develop long-term strategic plans for the rover they used flip charts to brainstorm and lay out scientific hypotheses. This work practice had a clear structure that could benefit from a computer tool," says Trimble. "We developed a MERBoard plug-in, called Sol Tree Tool, that utilizes the existing work practice that we saw on the flip charts, but adds multiple views, storage and retrieval of plans, presentations to groups, ubiquitous access throughout the mission support area, and the capability to compare plans against mission success criteria. The team adopted Sol Tree Tool as their standard work practice for rover strategic planning."

A standard set of tools for collaboration comes with each board—including a whiteboard, a Web browser, and a ubiquitous storage space that contains individuals' files and personal information for use in the collaborative computing space. The MERBoard has a plug-in architecture that allows customization for specific environments. MER plug-ins include the Sol Tree Tool, as well as situational awareness and data access tools from Ames' MER Collaborative Information Portal (MERCIP). Other missions are working on different plug-ins. All MERBoard tools can utilize the MERBoard's standard services for remote access and control, and for saving, recalling, and sharing data.

The collaborative computer

The MERBoard is a new category of computing platform that facilitates collaboration. Although inspired by IBM's BlueBoard, which was designed for spontaneous hall meetings and conference-style collaboration, the MERBoard extends the concept to support the more complex tasks of the NASA MER mission. The MER operations team has eighteen MERBoards distributed over three floors of the operations facilities, and in the rover testbed.

MERBoard uses commercial-off-the-shelf hardware consisting of a 50-inch plasma screen with touchscreen overlays, backed by a standard computer. The MERBoard computers are networked to a central server and database.

The software is written in the Java™ language. The plug-in architecture accommodates both Java plug-ins, using an application programming interface (API), and non-Java applications using sockets. MERBoard personal client software, which supports the exchange of data between personal computing environments and the MERBoard, runs on multiple Java platforms, including Windows®, Macintosh®, Linux®, and UNIX® systems.

MERBoard's core applications

MERBoard's four core applications are the whiteboard, the Web browser, the Virtual Network Computing (VNC) tool, and the MERSpace (an information depository). The whiteboard is the primary workspace, enabling scientists to sketch and brainstorm, annotate images, and create simple flowcharts. The whiteboard's "tabs" enable users to quickly flip from one board to another. Since the whiteboard uses the Scalable Vector Graphics (SVG) file format, drawings can have multiple editable objects that are easily saved and retrieved. Objects from external SVG-compatible applications can also be easily imported and edited.

The Java-based ICEbrowser™ provides access to the wealth of information available on the Web, including other Web-based tools specifically created for the MER mission.

The VNC supports communication and control between MERBoards, and also enables scientists to install a client on their laptops or workstations to control the MERBoard from their computer, or vice versa.

A MERSpace represents individual content in the collaborative computing space, and is available on each MERBoard for storing files, documents, and bookmarks, including complete whiteboards. It also provides automated one-button access to an individual's remote computer—a personal computer that can be displayed and controlled from a MERBoard. It also enables content created on one MERBoard to be presented or used at another, supporting the sequential nature of MER operations planning.

In addition to the core applications, MERBoard provides two globally accessible meta-tools—"screen capture" and email. Screen capture enables users to place images from different applications on the whiteboard for annotation and comparison. Email allows users to send MERBoard information to other users.

Visual clarity and smooth collaboration

"MERBoard allows us to do planning for the mission in a very efficient way," says Andy Knoll, Harvard professor and MER mission science team lead. "First, we can create things that are visually clear. Second, we can save these and email them to people or have them called up later or bring them up in another room."

MERBoard has added value to the MER mission by facilitating collaboration and working smoothly with the critical-path tools provided by JPL.

–Larry Laufenberg

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NASA CICT Program Office
Ames Research Center
650.604.2494

Program Manager
Butler Hine

Deputy Program Manager
Bill Van Dalsem

Infusion Editor
Larry Laufenberg
llaufenberg@mail.arc.nasa.gov

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